CONSTRUCTION INDUSTRY PLANT SAFETY GROUP

Good Practice Guidance for Use of Machine-mounted Human Form Recognition Systems

CPA CollectiveMark

Use of Machine-mounted Human Form Recognition Systems

Good Practice Guide

Front cover picture depicts a 360-degree camera with HFRS capabilities enabled.

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Foreword

The use of human form recognition systems is an emerging technology that can have applications in the construction and allied sectors as an aid to the minimising of contact between workers and others when in the vicinity of an active item of plant. Health and Safety Executive (HSE) data indicates that being struck by a moving vehicle account for most workplace fatalities after falls from height.

Although people/plant interface control measures, particularly with regards to physical separation, are the essential priorities to minimise contact with persons, there are cases where direct support and other workers may be deliberately or inadvertently within the potential area of an active item of plant. Their presence however may not be evident to the machine operator due to the configuration or design build of the machine.

Technology may assist an operator in identifying who are in a danger area. However, with various systems and equipment being fitted to a large range of mobile plant, along with a need to ensure a consistent and pragmatic approach, the construction and plant sector sought guidance. This has subsequently been undertaken by the Construction Industry Plant Safety Group, an industry forum that identifies and promotes safety-related good practice.

This good practice guide has been developed by a working group consisting of plant owners, construction contractors and equipment suppliers to devise this as guidance. This is to advise and inform owners, users, operators, managers and third-party suppliers on the requirements considerations for the fitment, use and management of Human Form Recognition systems (HFRS) installed on construction plant machinery to detect and warn of human presence in defined danger zones.

It should be noted that at the time of publication, HFRS is still an emerging technology and with limited applicable standards currently available, some of the technical specifications within the content of this publication are an industry aspiration which aims to meet the needs of the sector in the provision of reliable and accurate systems. Although HFRS are currently only safety aids to people/plant interface requirements, OEMs and suppliers are working in partnership with the sector to encourage future developments of trustworthy products and systems.

I thank the working group for their time and efforts in producing this guidance and to those who have produced supporting material and research reports. This guidance is technical in nature, for which the working group have devised a companion summary publication that outlines the key points of this comprehensive version.

I urge industry to note and adopt the good practices detailed within this guidance publication as effective means to minimise people being struck by moving machinery.

Aaron Davis

Chair of the Construction Industry Plant Safety Group HFRS Working Group

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1. Introduction

The purpose of this document is to set out the requirements for the specifying of, fitment, use and management of human form recognition systems (HFRS). These are defined, as is Section 2, as a multi-sensor, modular system capable of detecting physical human form around mobile plant and machinery and can encompass different technologies LIDAR, radar, other sensor types including those that provide 360-degree views, coupled with appropriate software. This guidance is broad however and should cover the main systems in use.

The document further provides guidance on the handling and management of data that is captured by the technology of these systems, as well as the legal requirements for those who have access to captured data.

Outcome of the use of HFRS - An Industry Statement

As part of the development of this guidance, the industry working group have defined an 'industry statement' on the outcome-of-use of HFRS. In essence, to apply a principle of future HFRS as an aspiration by industry for industry, that HFRS should as a minimum provide the following attributes and continually aim to better, but not be limited to:

a) Recognising a human form in pre-determined unsafe areas;

b) Determining both the safe and unsafe zones of a particular plant type;

c) Providing an appropriate range of internal and external warnings;

d) Being consistent in operation, with a high level of accuracy and reliability;

e) Being feasible and available in terms of technology and costs;

f) Collect data for analytical purposes to aid the identification of unwarranted incursions.

The Health and Safety at Work Act 1974 places a series of general duties on the employer in terms of providing a safe place of work for their employees, self-employed and to persons other than their employees. Additional requirements include the provision of plant and systems of work that are – in so far as reasonably practicable, safe and without risks to health. There is also a requirement for employees to co-operate with the employer in the execution of their duties.

HFRS are being specified and fitted to plant and equipment as an aid to prevent, as far as is reasonably practical, the contact between a person and machine which is active in movement, whether the component of a machine or the machine itself in terms of mobility.

The fitment and use of these systems is, and can only be, a part of a managed system for people/plant interface control measures, with physical and enforced separation remaining the key priority. It is important to note that HFRS are not 100% failsafe and limitations apply, with further information found in Annex B.

Current HFRS use sensors and software to recognise the human form through shape, and distinct and defined characteristics of motion by the system sensors and associated software. The software determines if the form is human as opposed to other shapes and characteristics e.g. a plastic bag blown by the wind, and as to where that human form is in relation to the relevant sensor range.

This subsequently provides a series of indications through signs and warnings etc. which are relayed to those operating the machine as well as those in the vicinity of the machine if a human form is detected within a defined set of parameters, such as distance from the sensors and within pre-determined zoning.

Once a detection is made, there needs to be a managed process of reducing that risk through initial stopping of the machine, and any subsequent prevention and learning.

Detections need to be acted upon both at a local-intervention level for both the operator and those who've infringed the danger zones as well at management level as part of a review of control methods.

HFRS further collects, stores and relays a set of data, of which the scope and depth of data will depend upon the relevant system, but likely will record numerical data such as the number of incursions within the set parameters, timings and GPS-location of incursions etc. Most HFRS systems have the ability to visually record when an incursion occurs with varying level of detail, depending again on the relevant system. Some systems are able to identify sufficient human detail so that an individual's identity can be made. See Section 5.

This HFRS alert data can further be collated, processed and analysed to provide further details on single and collective incursions, allowing controllers and managers the opportunity to establish improved ways of preventing incursions. With data being collected and available for analysis, compliance requirements may need to be followed in terms of the General Data Protection Regulations (GDPR), which governs how personal data of individuals is processed and stored.

A key part of any people/plant interface control measures is the application of learning and behaviours for those in and around the machine to understand the technology and what it does for them and others.

Use of these systems forms part of the risk assessment and any fitted system should be regarded as an aid to safety and complementary to the overall people/plant interface control measures. They should not be the sole reliant factor for ensuring that persons are clear of the danger area of an active machine.

A hierarchy of control for people/plant interface should remain paramount to ensure that those working within or external to the activities of the relevant machine are clear of any machine movement that is a risk to those in the vicinity. A hierarchy of control is further established in Section 4.

Regulation 4 of the Provision and Use of Work Equipment Regulations (PUWER) 1998 sets the benchmark for suitability of work equipment and that requirement must be considered when developing, fitting or managing any equipment for use at work. For any systems used in the detection of people, the required level of reliability (safety integrity level/ performance level) should be greater than for systems designed for general object detection.

Figure 1: example of HFRS sensing zones

A safeguarding consideration is that HFRS should not erode any elimination of the risk, i.e. separation between people and vehicles. However, where there is interaction between vehicle and people, reliance remains on the vehicle operator adequately monitoring the work area and acting appropriately, which reinforces that any HFRS is only a complementary means of providing warnings to the person in control of the machine and pedestrians.

The Construction, Design and Management (CDM) - Regulation 27 requires that:

- *a construction site must be organised in such a way that, so far as is reasonably practicable, pedestrians and vehicles can move without risks to health or safety.* This regulation states the requirement for sufficient separation between vehicles and pedestrians to ensure safety or, where this is not reasonably practicable;

> *(i) other means for the protection of pedestrians are provided; and*
>
> *(ii) effective arrangements are used for warning any person liable to be crushed or trapped by any vehicle of its approach.*

CDM Regulation 28 is specific to vehicles and additionally requires: *Where a person may be endangered by the movement of a vehicle, suitable and sufficient steps to give warning to any person who is liable to be at risk from the movement of the vehicle must be taken.*

Human beings are more capable of recognising a person and able to distinguish between a person and an object. However, their ability to maintain that level of awareness and response can vary considerably over time. It is because of this acceptance, that society can be more tolerant of “human error” as opposed to machine error.

Where a vision system influences safety, then there is a potential that this may diminish reliance on or by the machine operator. The following are suggested criteria to assist in establishing key safeguarding requirement that should be met:

a) A risk assessment should be carried out, considering the use of HFRS for the activity and machine type, based on relevant standards that has been supplied by the OEM/supplier of the equipment, which confirms that necessary safety criteria has been established as a safety aid;

b) Evidence of reliability should be provided including what testing has been carried out on the model of HFRS, together with field testing following integration to the particular machine, and to what recognised criteria;

c) HFRS should include a data logger, such that if an unforeseen event or unintended behaviour of the in-service device occurs, interrogation is possible in order to identify any vulnerability or configuration error.

d) Additionally, to gain reliability, the detection system should have a means of self-diagnosis and additionally, that regular checks are undertaken by the user to confirm the system is functioning as intended;

e) False positives or negatives - are incorrect or misleading results that HFRS could generate. The OEM/supplier should be able to demonstrate how errors have been minimised e.g. how false positives or negatives cannot be foreseeably caused by a variety of factors - including insufficient training data, incorrect assumptions made by the model, or biases in the data used to train the model;

f) Data threats - where a cyber-attack occurs when malicious or corrupted data is introduced into the data sets, could cause the HFRS to produce inaccurate results or degrade its overall performance. The system supplier should be able to show how software corruption is prevented, using the latest cyber security and data security methods as collected by the machine but is post-collected data;

g) OEMs/suppliers should ensure that their platforms and equipment are compliant with guidance from official bodies such as those issued by the National Cyber Security Centre

2. Definitions

command language

one that is readily interpretable by all those affected by a command

cyber security

protection of computer software, systems and networks from threats that can lead to unauthorised information disclosure, theft or damage to hardware, software, or data, as well as from the disruption or misdirection of the services they provide

data storage organisation

an organisation that has a physical location and has computing IT hardware systems and hardware equipment such as servers, data storage drives and network equipment able to store data

detection zones

defined and pre-set area where HFRS identifies physical human forms

false positive reading

alarm is activated where no human form is present in the detection zone

false negative reading

alarm does not activate where a human form is present in the detection zone

heatmaps

graphical representation of data that uses a system of colour to represent different values in a given area

hierarchy of control

determining actions that best control exposures to risk in a sequence of action levels

hirer/user

the individual or organisation that hires in or uses a machine for a work activity and who specifies and/or employs the use of HFRS and is responsible for the correct application and use

human form recognition system (HFRS)

a multi-sensor, modular system capable of detecting physical human form around mobile plant and machinery

GDPR

General Data Protection Regulations - which controls how personal information is used by organisations

OEM

Original Equipment Manufacturer – the organisation that designs, produces and supports HFRS parts and equipment that may be marketed by them or another company

sensor

device that identifies and produces and output signal for the purpose of detecting physical human form

supplier

the organisation that distributes HFRS to plant owners and users

systematic approach

a disciplined and methodical way of understanding, analysing and solving complex problems or processes in a methodical way

thumbs up

a visual signal, either electronically conveyed or physical, given by the machine operator to an individual wishing to enter the established hazard area of the machine

true positive reading

alarm activates which correctly detects an incursion in the detection zone

true negative

alarm does not activate as no incursion is detected and there is no incursion has been made

transgressors

those on foot who enter the established hazard detection zone

zoning

defined area around a machine where appropriate actions for specific controls are required

3. Types, Functions and Fitment

3.1 Scope of functionality

HFRS is designed to utilise technology to identify the human form in defined zones of detection and provide suitable warnings to both the machine operator and the transgressor(s). Use of these systems should form only a part of a site-management risk assessment and method statement requirement, with any fitted system should be regarded only as an aid to safety, complementary to the overall people/plant interface control measures.

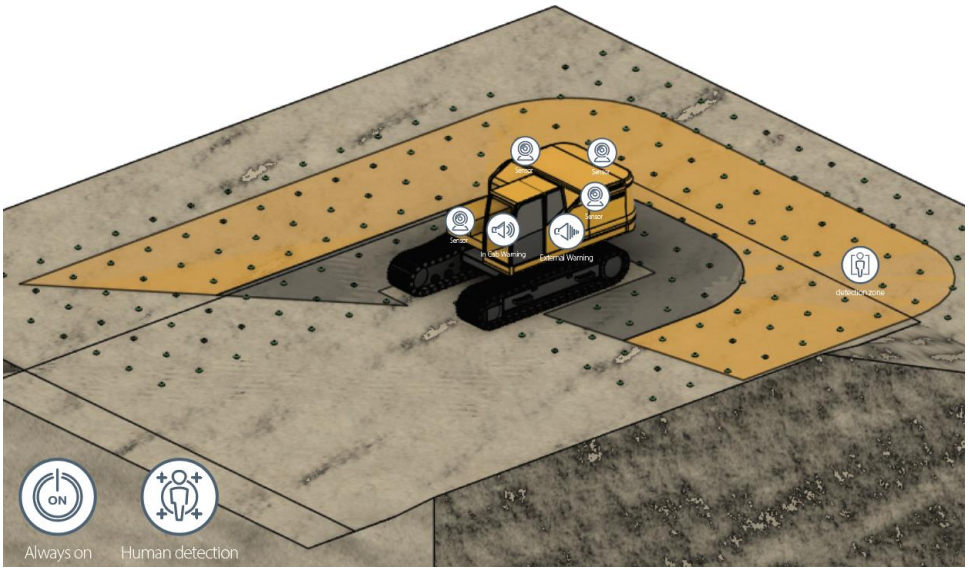


Figure 2: Initial zoning requirements

3.2 Scope of machine types

HFRS technology is being increasingly developed to be fitted to a wide range of plant, whether self-propelled or where activity movement occurs whilst positioned statically. Depending upon the machine types, their aim to eliminate areas of the machine's zoning where the operative in certain or typical operational situations has limited visibility to areas of the machine. Although non-exhaustive, Section 3.4 details a range of construction-based plant that HFRS, for the purposes of this publication would normally apply to. The scope of equipment can be wider, depending on the sector, plant type and application.

It is important that HFRS is not the sole reliant method for ensuring that all persons are clear of the danger areas of an active machine.

3.3 Setting of Alarms

To set up the alarm system, the required detection zones need to be established and are dependent on many factors. Industry guidance has determined a suggested set of distances as an initial default establishment point. See Section 3.4.

Distances however are very dependent on the working area and machine type and other factors and is only an initial starting point, from which each machine setting needs to be tailored to customer requirements. See Section 3.12.

The hazard zones need to be identified and relevant to a number of factors, determined by a risk assessment and method statement, drawn up by a competent person that takes into account, the factors identified in Section 4.

The illustrated detection zones in Section 3.4 are based on areas around the machine for which the operator, seated or positioned within the operator station, has limited or masked view (blind spots) of that area because of the machine's design or configuration. Some of that limited or masked visibility may be permanent e.g. concealed by a fixed part of the machine or variable, movement of a component during the work activity. Masked areas/blind spots – permanent or variable - needs to be identified by a risk assessment. The detection zones illustrated in Section 3.4 should only however be regarded as a recommendation.

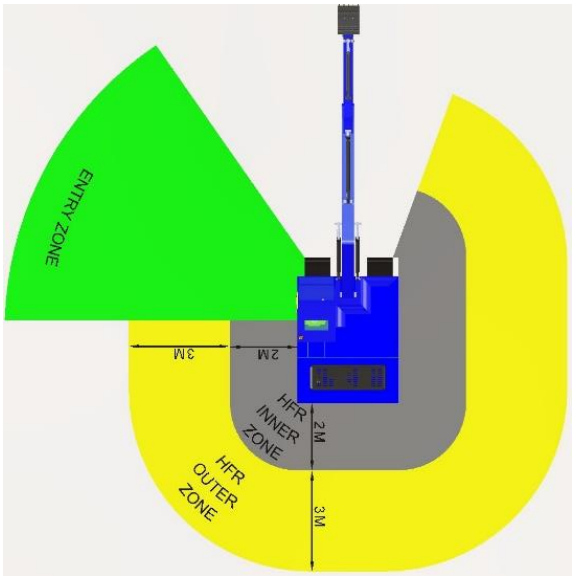
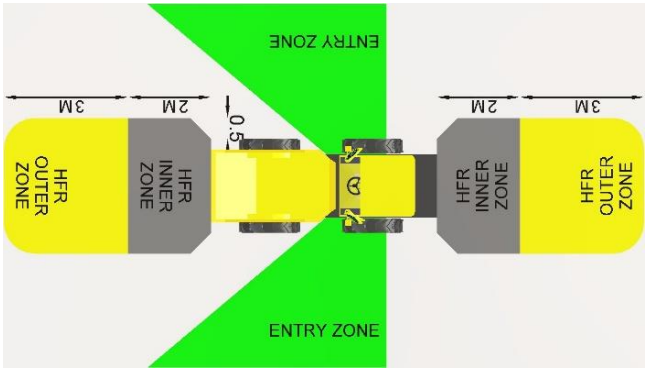
There needs to be a clear authorisation process on how and who determines the hazard and detection zones, and who is authorised to amend HFRS settings to account for different factors and capabilities of those changing settings. Section 4 provides further information on authorisation requirements.

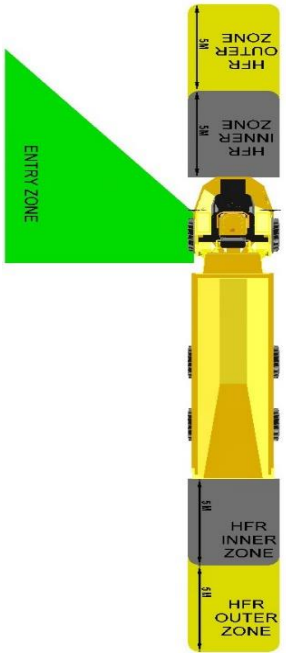
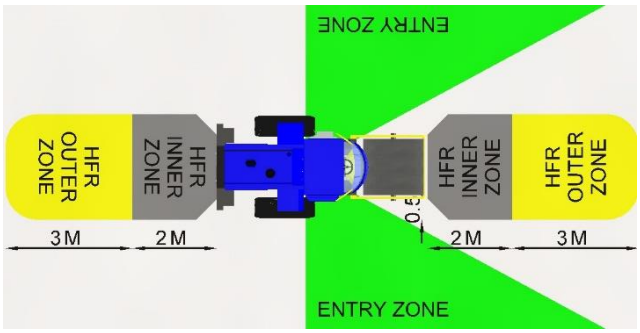
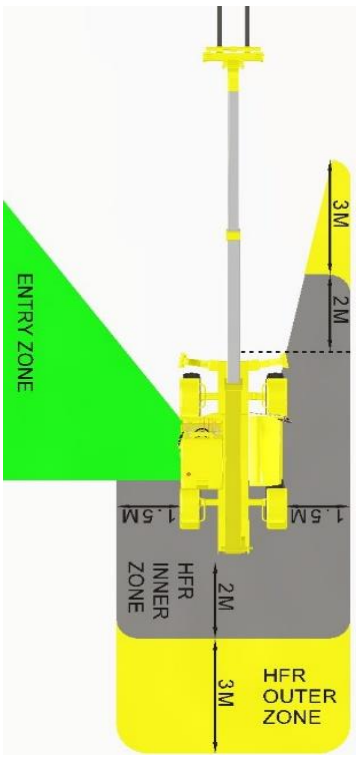
3.4 HFRS Detection Zones

The following are recommended minimum detection zone configurations for a range a typical construction equipment types:

Note: For clarification, the indicated coloured zones in the following illustrations relate to the initial HFRS activation zoning. The relevant colours used are only illustrative for this section.

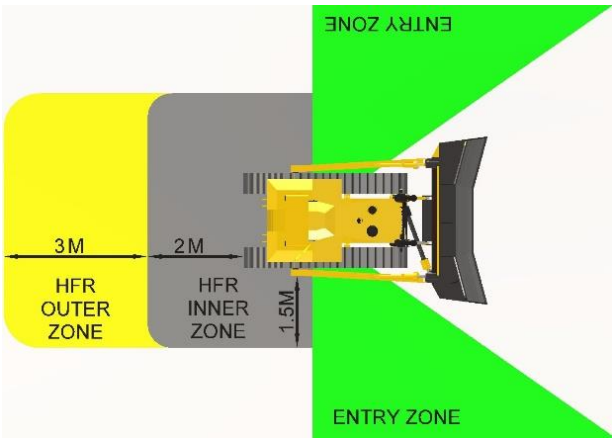
3D versions of the images are portrayed in Annex E.

a) 360° Excavators • Coverage: 360° recording, 250° detection area (*as per diagram below*) - based on upper structure movement • Inner zone: 0 – 2m *(from edge/perimeter of machine)* • Outer one: 2 - 5m • Zero blind spots requirement	
b) Forward Tipping Dumpers • Coverage: Front & Rear detection • Inner zone: 0 - 2m • Outer zone: 2 - 5m • Minimum 160° coverage at front • Minimum 160° coverage at rear.	

c) Articulated and Rigid Dump Trucks • Coverage: Front & rear detection • Inner zone: 0 - 5m • Outer zone: 5 - 10m • Extended detection range for sizing requirement.	
d) Rollers/Compactors (cabbed types) • Coverage: Front & rear detection • Inner zone: 0 - 2m • Outer zone: 2 - 5m • Side detection where applicable.	
e) Telehandlers (All Sizes) • Coverage: 250° , 360° recording • Inner zone: 0 - 2m • Outer zone: 2 - 5m • Boom position compensation may be required • Body sides detection zone **:** 0m – 1.5m zone (HFR inner zone).	

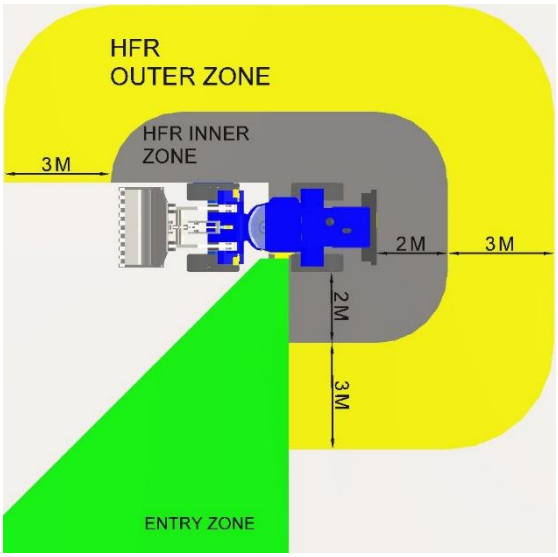
f) Dozers

- Coverage: 180°, rear coverage, front detection where required, if available or feasible
- Inner zone: 0 - 2m
- Outer zone: 2 - 5m
- Body sides: 0 - 1.5m detection zone.



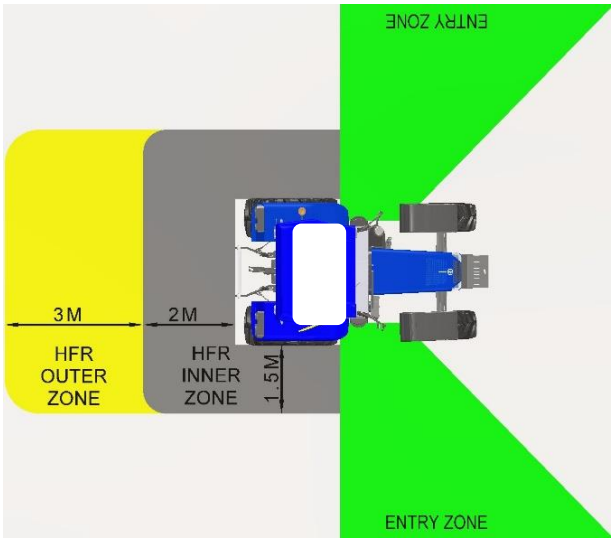
g) Wheeled Loaders and 180° Excavators

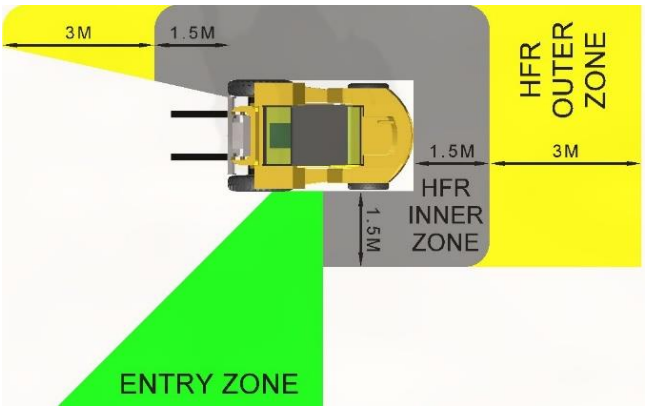
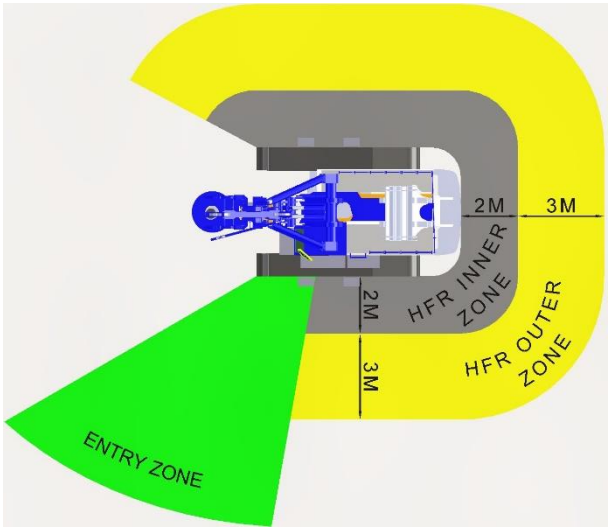
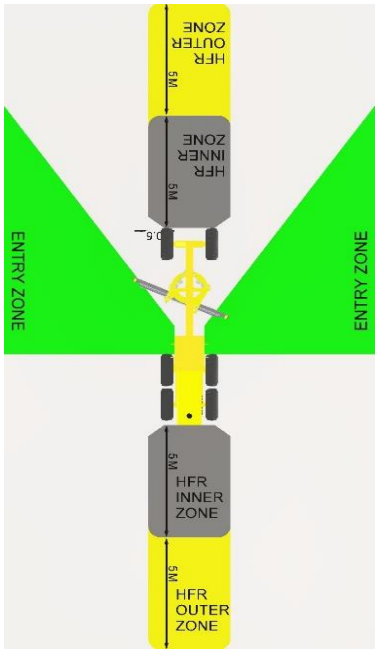
- Coverage: 270°, 360° recording
- Inner zone: 0 - 2m
- Outer zone: 2 - 5m
- Articulation compensation may be required.

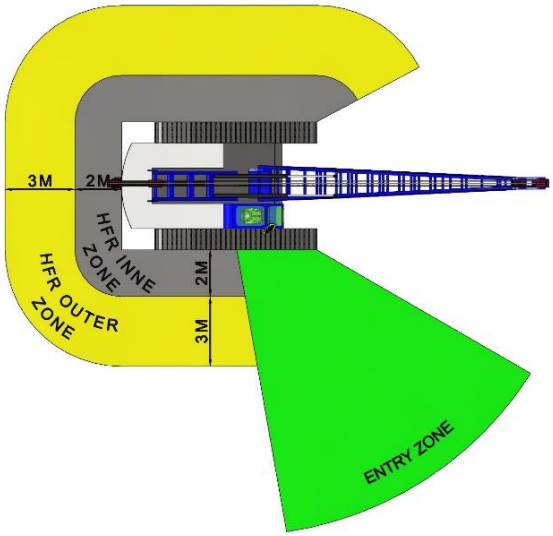


h) Agricultural-based Tractors

- Coverage: 270° detection – dependant on required implements
- Inner zone: 0-2m
- Outer zone: 2-5m
- Forward facing recording may be required.



i) RT lift Trucks - masted • Coverage: 180° rear coverage, front detection • Inner zone: 0 – 1.5m • Outer zone: 1.5 - 5m.	
j) Piling Rigs • 250° detection coverage, 360° recording - based on upper structure movement • 0m – 2m zone (HFR inner zone). • 2m – 5m zone (HFR outer zone)	
k) Graders • 5m front & rear detection zone • 0m – 5m zone (HFR inner zone) • 5m – 10m Zone (HFR outer zone)	

l) Crawler Cranes • 250° detection coverage, 360° recording - based on upper structure movement • 0m – 2m zone (HFR inner zone). • 2m – 5m zone (HFR outer zone)	

3.5 Cab design, readouts and interpreting

The fitting and use of HFRS requires consideration for the location of any equipment and components that needs to be located and installed on a machine. This will include monitoring and warning equipment located within the machine's operator station.

Factors that need to be determined when equipment is being installed in an operator station environment should include:

- Ensuring that essential and effective external visibility is not obscured;
- That other fitted machine monitoring or controlling systems are not affected through performance and activation;
- That monitoring and warning equipment is at a level and distance so that eye contact can be maintained without obscuring other equipment and systems;
- That installed equipment and the monitoring and warning systems, minimises the workload of the operator and any cognitive overload.

Note: *the Health and Safety Executive produce guidance on the Assessing Field of Vision for Operators of Earth Moving Machinery on Construction Sites at:* *https://www.hse.gov.uk/foi/internalops/sims/constrct/020702.htm*

Monitoring and warning systems should be able to provide the following types of information to the machine operator and those who are detecting within a defined zone:

- Provision of a system of internal and external alerts and directional information. See Section 3.7;
- Audible alerts need to be unique and distinguishable from other sounds and be sufficiently louder than of nearby ambient noise;
- Audible warnings need to readily interpretable by the operator, any transgressor and others nearby;
- Audible alerts need to be determined based on user requirements, including the plant type and visibility ability, which will vary according to the working requirements and on what system is specified.

Figure 3: Example of cab-fitted HFRS monitoring equipment illustrating numerous OEM and additional information systems presented to the operator

It is recommended that spoken alerts are specified for inner zone internal alarms, being a high-risk situation and takes into account operator cognitive overload.

The language used to provide a warning or command language needs to be both consistent in terms of intensity and volume location, ideally in a single understandable language that is in line with other equipment on the same site/workplace. The language should be determined by user of the equipment.

Any audible command given to be relevant to the type and strength of warning required and relative to the machine configuration.

3.6 Sensor Specifications and Functions

As a basis for machine-mounted HFRS, they should:

- Be able to function in low lighting and high lighting conditions e.g. direct sunlight as well as fog, snow, rain etc;
- Meet a suitable ingress and other protection-rating requirements;
- Have a compatible power supply using the host machine's system;
- Be able to function in a wide range of temperatures;
- Have a high humidity tolerance;
- Be mountable and adjustable over a wide range of planes;
- Provide a sensor fault alarm e.g. if disconnected, covered, dirty, damaged etc;
- Have a self-diagnostic processing capability;
- Be resistant to the environment they are to be used e.g. dust, heat/temperature etc;
- Be cleanable.

Suggested requirements for unit processing should include:

- Continuous operation capability;
- Self-diagnostic functions, which provide fault warnings to operators;
- Tamper detection;
- Obstruction detection;
- Minimum of 250 hour data storage capacity;
- Able to transmit data taking into account the location, remote use, reception capability etc;
- GNSS capability.

Figure 4: Example of rear-mounted sensors

3.7 Internal and external alarm settings

HFRS fitted onto plant should have internally and externally available alarm settings that warns both the operator and those within and around the machine, that the relevant zones have been transgressed and that appropriate internal and external alert-based warnings are given. Section 5 provides further information on detection alerts monitoring and collation.

Systems should be able to provide alert warnings that include:

a) Internal Alerts:

- Outer zone: an indicative or differing audible alert, plus a visual indicator when a pedestrian enters a pre-defined zone;
- Inner zone: a suitable unique alert – as required by the user – e.g. alert plus a visual indicator plus an audible continuous alert that has a higher audible tone or volume, which is more intense than that for an outer zone alert.

b) External Alerts:

- Configurable spoken warnings such as “Danger – move away” or “Caution – machine in operation” etc. that is hearable and distinguishable by transgressors around the machine e.g. utilising additional speakers.

Consideration needs to be given to outer zone internal alerts, where continual false alerts may cause the operator to disregard, or become complacent to, continual alarms and be of a tone and volume that - although may be triggered - should not be deemed as a nuisance by and to the operator.

The fitment of self-adjusting alarms, which can adjust to a higher decibel rating above the ambient noise level, can provide a more effective audible alert.

When a machine is inactive, whether temporary e.g. with a safety lever employed, or permanent e.g. rest breaks etc. external alerts need not be provided, although internal notifications may be supplied See Section 4.5.

3.8 Visual Alarms

When a pedestrian is detected, a visual alarm should provide additional warnings in addition to the external alarm to the machine operator and the transgressor. The visual methods should comply with the following criteria:

a) Internal:

- Visual zonal alert that stays illuminated - outer zone or inner zone - while a person remains present within the zones;
- Warning displayed on a visual display screen (optional).

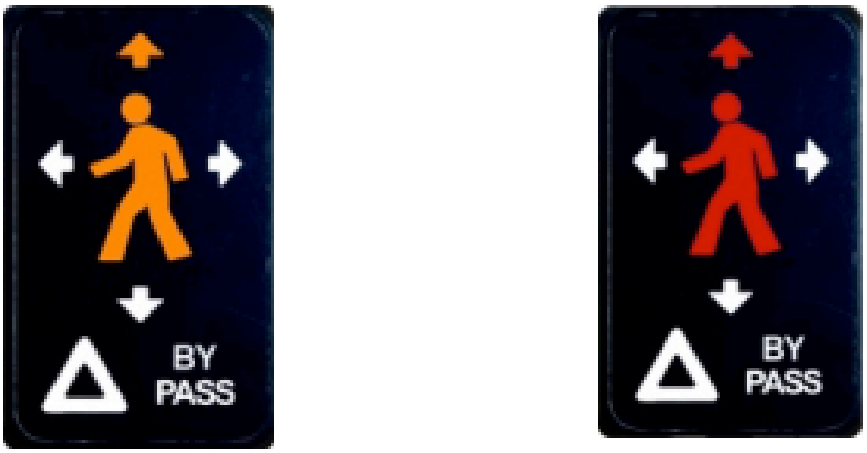


Figure 5: Example of visual internal alert notification

3.9 Factors for installation

When mounting HFRS onto items of plant, the following requirements and conditions should be observed to ensure effective and accurate performance of system components:

- Suitability of a particular system for the intended host machine;
- Supply of installation instructions from OEM/supplier;
- Hardware and software is installed as per the given OEM/supplier specifications;
- Installed by trained, competent and authorised persons;
- Sufficient number of sensors and positioned to achieve the specified coverage;
- Protection from potential mechanical damage;
- Protection from a range of environmental factors;
- Accessibility considerations regular maintenance;
- Effective cable routing and cable protection to avoid damage, wear and tear - particularly on exposed parts of the machine.

3.10 Manufacturers initial documentational requirements

When fitting and setting up HFRS equipment, component and ancillary items; suppliers should provide a set of requirements to be followed by those installing the equipment to the relevant plant types and supply information relating to:

(cont'd)

a) Factors for initial calibration and commissioning requirements which should include:

- The required initial zone calibration;
- Verification of the required detection zones;
- Documented records of calibration settings;

b) Factors for initial testing on initial commissioning which should include:

- Full system functionality verification;
- Detection zone validation;
- Alert system testing;
- Data logging verification;
- Communication system testing.

c) Factors for periodic testing and ongoing maintenance (normally by the user) which should include:

- Daily operator checks required;
- Weekly system verification;
- Monthly performance validation;
- Quarterly comprehensive testing;
- Provision of technical information to users inc. product familiarisation etc.
- Training of installers, testers, maintenance staff etc.

3.11 Maintenance requirements

Regular Maintenance forms part of the owner and user requirements in line with the requirements of the Provision and Use of Work Equipment Regulations 1998 (PUWER).

The maintenance regime should take the following factors into account:

- Sensor cleaning schedule;
- System diagnostics;
- Software updates;
- Hardware inspections;
- Calibration verification.

On handover of installed plant, an agreed approach to maintenance should be determined by both the user and owner. A management process should also be agreed and implemented between the owner and user in the case of HFRS faults and include:

- Immediate reporting of system faults;
- Machine operation prevention if faults are detected;
- Documented fault resolution procedures;
- Verification testing after repairs.

If a fault is detected, the machine should be taken out, or not put into operation, until the faults are rectified. However, where required, the machine may be used with inoperative HFRS but only after being subjected to a risk assessment which follows the considerations and requirements outlined in Section 4. The risk assessment should be devised by the machine user.

Annex A provides further guidance on fault reporting and procedures.

3.12 Re-calibration for various customers and environments

To meet user/customer requirements, plant owners and suppliers will need the capacity and means to alter HFRS-supplier default settings, or settings amended to suit previous users, based on a given criteria. Factors that determine user-bespoke settings include use in urban environments - where detection zones may need to be reduced to physical limitations - and where numerous operatives or nearby pedestrians external to the work site may be detectable within the set detection zone.

Factors that determine the detection settings and minimum distances for urban working areas should include:

- Machine type and size;
- System type;
- No of Sensors and positioning on the machine;
- Machine configurational movement and distances;
- Activity being performed by the machine;
- Location of authorised pedestrianised walkways;
- Physical exclusion control methods;
- Supervision and marshalling of pedestrians;
- Nearby non-works related human activity;
- Other plant activity;
- Changing worksite layout.

Section 4.6 outlines further considerations when recalibrating for specific environments and situations in lieu of the recommended default settings that have been agreed by industry, as in Section 3.4.

3.13 (Hirer) PDI and Inspection Requirements

A series of checks and inspections requirements needs to be undertaken on completion of fitment to a machine type and when prepared for hire by the plant owner to other nominated organisation and individuals. The checks and inspections should ideally cover the following, but be tailored towards each system manufacturers requirements:

a) Equipment identification;

b) Visual component inspection;

c) System power-up;

d) Zoning verification;

e) Alert system checking;

f) Faults identification and reporting;

g) Sign-off and approved for use.

The requirements for checks and inspection should be supplied by the HFRS OEM/supplier for the particular type.

Where machines are hired in, the requirements for any disablement of HFRS needs to be determined between the owner and hirer. Annex D provides further information on the issues of active or inactive HFRS and responsibilities under data protection requirements.

3.14 Limitations of use

A number of factors need to be taken into account when procuring, installing, setting up and using HFRS.

As these are aids to safety in terms of detecting human form in defined hazardous areas - and as with any safety-related system - reliance should not replace any base safety factors and not impact on existing established safe systems of work. This includes effective planning and separation, digital ‘thumbs up’ and other external signalling or information display systems.

HFRS equipment themselves should not be become a hazard e.g. restricting in-cab visibility, create or increase cognitive overload and not override existing support systems such as training. See Section 3.5.

Factors that should be considered for HFRS use include, but not limited to:

- That they are not 100% reliable in accurate detection;
- May be limited by maximum operating temperatures;
- Can be affected by condensation, rain, fog and extreme wet weather conditions;
- A reduction in accuracy through external factors, low sun etc.
- A reliance on constant cleanliness of the sensors;
- Requires effective installation and setting up inc. installer competencies;
- Requires in-cab components to be readable but unobtrusive;
- Cannot be considered a total control measure;
- Ensuring that they do not impact, control or affect machine functions e.g. emergency stopping;
- A reliance on operator and operative training and behaviours to react to warnings etc.

3.15 HFRS Updates and Future proofing

With the technology of HFRS and implementation of artificial intelligence (AI) becoming advanced, HFRS equipment will continually advance in capacity, capability and availability. However, consideration needs to be made on that on purchase, that the relevant product needs to have a reasonable and serviceable operational effectiveness to balance purchasing and updating costs to plant owners and users.

Equipment at the time of purchase from the marketplace should be able to both maintain and have updatable software and hardware. Industry has suggested an expectation of a timescale of at least five years, albeit dependent on the rate or evolution and required functionality. HFRS should have an update capability able to be passed onto any subsequent owner of the machine.

3.16 Systems accuracy

Accuracy testing is a key factor with the use of HFRS, where low accuracy may result in a lack of human form detection or false detection of human forms. This ultimately either reduces trust with the system or prevents accurate detection, which can lead to both potential incidents and distrust of HFRS. As accuracy performance may vary across different organisations and as technology advances, a defined accuracy level cannot be documented in this publication. Owners and users need to apply a level of due diligence in determining the accuracy levels and what standards have been applied e.g. through bodies such as MIRA, by the OEM/supplier. Annex B provides further information on industry-sought HFRS accuracy levels and requirements.

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4. Management of Systems on Site

4.1 On-site Management

Once received by the user and/or the relevant organisation, the use of HFRS needs to be incorporated with the Principal Contractor's overall health and safety management arrangements in compliance with the Construction, Design and Management Regulations (CDM). This includes controlling access, supervision and training, and the controlling of contractors in ensuring that any work is planned, managed and monitored so that it is carried out without risks to health and safety. Section 6.6 defines the responsibilities of the user/organisation.

4.2 Operator/site Daily and pre-use checks

As a key aid to safety, effectiveness of HFRS accuracy is partly dependant on the carrying out of specific pre-use checks on units and equipment before commencing any work activities with the machine. Checks should be undertaken on a daily basis and in addition to the normal pre-use checks that are undertaken on the machine. Where shift changes may occur, checks on HFRS should be undertaken by the using-operator, with continual checks undertaken in inclement or harsh working conditions.

In principle, a systematic approach should be used and should encompass:

- Sensor cleanliness inspection;
- Display system verification;
- Zoning verification;
- Alert system testing;
- System fault monitoring.

Items for checking within a checklist should ensure that both the manufacturers and users required checks are covered and standardised across the same machine types. The OEM HFRS supplier's checklist content should be paramount in quantifying what regular checks need to be carried out and when.

4.3 Management/supervision checks

A systematic approach to ensuring that daily and pre-use checks are carried out should be introduced by those managing and supervising plant operations on site. This in principles is about applying a disciplined approach of understanding, analysing and solving the required process in a methodical way. A standardised approach to ensuring that checks are carried out should be detailed within the site health and safety arrangements plan which contains a compliance check. Suggested responsibilities for the fitment and use of HFRS can be found in Section 6.

4.4 Alarm Alert Notifications

HFRS fitted to plant need to be able to alert both the operator and those within the detection zones of any transgression through defined alert specific warnings (See Section 3.7). External alarms should have a supervisor-level deactivation system when working in noise sensitive areas, so that these can be turned off e.g. during night works or in close proximity to housing, providing the correct level of authorisation has been followed. See Sections 4.6 and 4.9.

There should be a notification process using, for example, a portal approach so that records are made when external alarms are disabled and by whom. There should also be a need to implement alternative arrangements e.g. direct supervision, when other noise pollution may mask or disguise any external alarms of the relevant machine.

4.5 Controlling of inadvertent alarms/false warnings

It is likely that due to a range of circumstances, that alarms may be triggered but where either the alarm was false - known as a false positive, or that there has been a genuine zone transgression.

The first principle to determine the nature of alarms being activated is the establishing of the site control zonal settings (See Section 3.4).

An agreed reporting process inc. reporting procedures should be implemented to minimise and introduce actions where false alarms are triggered which if unchecked, may lead to complacency with both the operator and site operatives. There may also be a temptation for the operative to tamper with the alarm system if cognitive overload is experienced from an excessive number of alarms.

A reporting structure should be implemented that includes site managers, HFRS manufacturers, installers and plant owners on the frequency and nature of false alarms. Inadvertent alarms should be classed as a system failure, depending on the frequency of false alarms and the severity of warnings given.

If the machine is in an inactive state e.g. not in a working mode e.g. where a safety lever has been engaged or where a handbrake has been released, any external alert notifications should be disabled, but the operator remains informed internally. Videos of detection should only be active when machine is in its working mode.

4.6 Authorisation for changing from default setting settings/zones

At site level, there should be an agreed and implemented process, with an authorisation hierarchy, when a change for zone setting specifications may be needed. See Section 3.12.

Where zones specifications need to be changed - as this can have serious consequences, the authorisation process needs to ensure that any approval is based on a site-specific specification that is over-and-above the pre-agreed client or contractor specified specification for that site.

Approval should follow a defined hierarchy of appropriate positions and tailored towards a specific site authorisation sign off by for example, a Project Director, Health and Safety Manager etc, who should be at the senior end of the responsibility hierarchy.

The reasons for a need to alter the pre-set zone settings are varied, but can be determined by where HFRS picks up for example, passing traffic on a motorway worksite etc. Where potential changes to the default detection zones have been identified as being required, specific risk assessments of the activities need to be implemented. See Section 4.8. However, a standardised approach to zone detection ranges and limits should be maintained wherever possible, with zone setting changes only occurring in exceptional and unique circumstances.

A list of factors that can affect zone settings can be seen in Section 3.12. Any required changes to the zone settings need to be actionable in a timely and effective manner, usually conducted either via remote wireless or via a connected device.

4.7 Hierarchy of controls

Controlled or exclusion zoning is commonly used in the construction industry to inform personnel of the dangers of working within close vicinity of an item of plant, component or activity.

HFRS has been developed to provide a level of assurance that any zone transgressions are identified. A system’s primary function is to inform the plant operator that a person has, or is about to, enter a designated exclusion zone around a machine.

Designated danger, exclusion and controlled zones around a machine should be a key component of an organisation's policies, procedures and hierarchy of controls in ensuring compliance and furthermore, form a basis for training requirements to site operatives and others who may be in the vicinity. See Annex C.

It always remains the responsibility of the pedestrian to never enter any exclusion zones unless the plant operator has made it safe to do so and has confirmed this effectively to the pedestrian. Where a self-propelled machine moves towards a nearby operative, they should have ben pre-briefed on the procedures to be followed so that they are kept clear of the machine's danger zones.

Hierarchy of Control

Level	Description	Risk Control Measures
1 Eliminate	People plant interface removed	Large fenced off area with people eliminated from the work area. Plant operates without marshalling.
2 Minimise	Full, physical separation of people and plant	Observe the plant safe zones by physically restricting people from entering the designated exclusion zones. Erect physical barriers around a single operation outside the maximum reach of the machine. This must be marshalled.
3 Minimise	Partial separation of people and plant	Observe the plant safe zones by restricting people from entering the designated exclusion zones using visual means, cones or spray marks that denote the zones. This requires increased supervision and measures to prevent unauthorised access.
4 Mitigate	No separation of people and plant	Exceptional tasks that require essential personnel to enter a designated safe zone (for example, kerb laying, disconnecting attachments, slinging loads, off-loading materials from fork lift trucks or lorry beds) must be mitigated through a robust site and task specific Safe System of Work. These tasks must only be conducted with: • Clear communication between the plant operator or vehicle driver and essential personnel performing the task. • A method of preventing non-authorised access. • A full time Plant & Vehicle Marshal/Machine Controller. • Increased supervision, and a strict discipline in executing the task exactly as written. Personnel must not enter the designated zone unless the machine is fully isolated, engine switched off and a method for preventing it restarting it inadvertently is in place

Figure 6: Example of a Hierarchy of Control

4.8 Factors for RAMS construction

Procedures for HFRS management, setting up, using and compliance should be evaluated and document within the risk assessment and method statement (RAMS) process.

When devising RAMS for site operations using a particular type of plant and fitted with a particular make and model of HFRS, the RAMS should take into account, but not be limited to, the following:

- Task or activity;
- Location and environment;
- Site layout and pedestrian/traffic routes;
- Machine type and configuration;
- HFRS type;
- Detection areas;
- Proximity hazards;
- Urbanised areas;
- Limitations of use;
- Noise levels;
- Operator and operative training; etc.

Although there may be similarities across a similar type of machine or system type, a standard-type RAMS should not be relied upon and any varying factors should be taken into account.

More information on RAMS construction can be found at: https://www.hse.gov.uk/simple-health-safety/risk/index.htm

4.9 Risk assessment/management on alarm disablement

There may be an occasional requirement to disable external audio alarms and only in the most serious cases, the visual warnings. Any disablement should be justifiable and relating to the outcome of a transgression that was not acted upon and which follows the authorisation hierarchy outlined in Section 4.6. Factors that may determine when external and internal alarms may be disabled could include, but not limited to, the following:

- Unique environment;
- Levels of transgressions;
- Number of false positives;
- Number of false negatives;
- When effective alternative control measures are in place;
- Site profile/other equipment etc;
- Public interface;
- Operator competency (to react to zonal transgressions)

4.10 Working near to pedestrian areas

Where a machine needs to work near to or in pedestrianised areas, normal separation control measures using physical-type equipment e.g. barriers should be the main control measure along with an increased level of supervision, without placing full reliance on HFRS.

The type of work and the environment will determine additional control measure that are required. Zonal setting adjustments may need to be made and in accordance with Sections 4.6 and 4.8.

4.11 Other control measures methods

Where HFRS needs to be disabled or settings reduced, other control measure should be adopted and may include:

- Exclusion zoning with barriers;
- High levels of supervision, marshalling;
- Physically-segregated working area;
- Machine component limiters e.g. slew limiters;
- Static activities only;
- Visual screening of a given detection area.

Figure 7: Typical example of a rear-fitted sensor to existing OEM rear-view hardware

5. Data Monitoring, Collection and Protection

5.1 Data collection, recording & storage

One of the attributes of HFRS is the ability to record and store a range of information, which them can be transferred externally from the machine-mounted system to any external storage facility. This transfer of information allows a review and a collation of data, which can be analysed in order to provide information for a number of reasons. Collection and storage of this data may hold personal information for which compliance requirements, such as Data Protection (GDPR) regulations, needs to be followed.

Note: *Organisations seeking to deploy the use of HRFS on plant are recommended to seek confirmation from the HFRS Supplier that a Data Protection Impact Assessment has been completed. More information on data protection and impact assessments can be found at the Information Commissioners Office - https://ico.org.uk/*

5.2 Data Points – (non-video)

The following is a list of minimum data points that should be required from HFRS:

- Company name – *refers to the company name where the data is being collected;*
- Incident ID – *Unique detection ID number;*
- Machine identification – *Plant/asset ID number*;
- Alert tag (Outer/Inner Detection Zone) – *Classification of detection;*
- Latitude – *for location of the detection;*
- Longitude – *for location of the detection;*
- Date (of alert) – *in a dd/mm/yyyy format*;
- Time (of alert) – *in a 24hr format*;
- API Supplier – *name of the OEM of the HFRS.*

HFRS outer zone

Depending on the system or user specification, outer zone detection videos can be stored locally on a fitted internal data storage device on the item of plant and numerical data of detection can be visible in any management reporting system.

HFRS inner zone

Inner zone detection videos (for example, a 10 second clip) – depending on the system specification - can be easily identified on the internal digital storage device. These clips may be downloaded and stored for ease of review by interested parties. Requests to the data owner, system owner or user may be required. All numerical data of detections should be visible in a data management reporting system.

Any data collection specifications should be in accordance with relevant parts of GDPR. Event, numerical and video data should be API (Application Programming Interface) capable.

5.3 Data collection, controlling, handling and ownership

Data collected by onboard HFRS systems can be transferable from the machine to a storage location, which could be the supplier, hire company, user or other appointed organisation.

It is important that temporary and permanent ownership and user-rights needs to be established prior to the machine and/or on-board HFRS being activated. This is usually at the contractual point of hire, or at the point of delivery and on collection of a machine if hired in.

There should be clear lines of engagement and responsibilities that is based on the type of data that is collected and stored, particularly where personal data and/or identification of an individual is possible, as well as being in compliance with GDPR requirements.

Annex D provides a legally-sought perspective on HFRS fitted to hired-in plant.

5.4 Data uses and analysis

All systems would likely be installed, ready to connect and transmit data to a portal, so that any data collected by the HFRS can be accessed and reviewed by those holding and using the data.

To be effective, ideally the reporting system should have a GPS-based mapping system containing an image of the site and overlaid with 'Heatmaps'. These summarise the number of detections and amalgamate them into readable and interpretable data. Heatmaps can allow rapid identification of problem areas so that the data can be reviewed and any causes of the problems potentially identifiable.

The data portal should be capable of providing data reports at intervals as required by the end user. The information required will likely be the detection data, together with the ability to interrogate the data to identify details of any detections.

Each user will specify their bespoke requirements and the format of this data will be specific to individual organisations.

When examining detection data, consideration needs to be given on what would be - for that particular activity, the main causes of transgressions e.g. work activity, site layout, machine type etc.

It should be noted that any data collected at a certain date or over a specified period may become aged or outdated quite quickly as site conditions change.

Figure 8: Example of heat mapping analysis

Likely levels of required information from collected data could include:

- Machine details inc. GPS location;
- Quantities of incursions – inner and outer zones;
- Location relative to machine of incursion – specific HFRS sensor(s);
- Times and dates;
- Identification of physical human forms in the detection zones.

5.5 Data Storage & Security

The data stored on HFRS on the machine should be protected with encryption, which would require specialist software to be able to view the footage and data contained on the data-storage format e.g. SD card.

The machine should always be left secure whilst unattended and requiring a key to access and safeguard the HFRS equipment which, if possible, should be hidden from view and not easily removable. Authorised organisations or users should have controls and procedures in place, with regards to the distribution of software, that prevents unauthorised users obtaining or gaining access to the software required to playback any footage directly from the on-board storage.

The data storage unit should be equipped with strong procedures for access protection in accordance with good practices and GDPR requirements, where relevant.

5.6 Security of data on an external server

Data can optionally be collected initially by the HFRS OEM and then shared where requested to an authorised organisation. Where the data has been downloaded from the machine and stored externally on a server - either with the HFRS supplier, machine owner or user - they are viewed as the data storage organisation and should have security measures in place that ensures that all appropriate actions required to comply with current data protection regulations.

The following paragraphs are examples of good practice requirements for data storage and security.

- Where an external data storage organisation is being used, it should be accredited and have at least a minimum level of and up-to-date certification requirements. It should further ensure that appropriate security measures are in place, which includes Firewall Security management, SSL for all HTTP traffic, and encryption at rest and in transit for all data.
- Any appointed data storage organisation should have full resilience and security measures in place. Regular backups should also be undertaken and that backup validations are performed.
- The data storage organisation should perform vulnerability scanning on all their critical systems and that systems are scanned internally prior to the release of new code to ensure no new known vulnerabilities are being introduced onto the live environment. All systems should also be vulnerability-scanned on a regular basis, ensuring an awareness of any vulnerabilities when they arise.
- The implementation of ‘automated penetration’ tests, using scanning software, should also be recommended, being a more in-depth scan that typically takes several hours and in some cases days to complete.
- Implement ‘Information Security’ reviews, where a full review of any other known potential risks is performed, should form part of the security checks along with annual penetration performance testing, performed by an independent accredited organisation.

- All data that is captured and used should be stored only within the jurisdictions of the UK or EU.

5.7 Controlling access of data

Access of a user's data by the data storage organisation should be controlled and limited to those who need access to the data. All those who access any information should take regular assessment based GDPR awareness, information security & cyber security awareness and phishing training.

Data protection training - which includes data handling, access and destruction procedures, should also be undertaken to ensure the confidentiality, integrity and availability requirements of the stored data are met.

In some cases, authorised organisations or users can set the minimum-security requirements of the platforms to suit their own requirements including:

- Password requirements (inc. minimum password length, minimum password strength, number of restricted historic passwords, maximum password failures, maximum failure time period, duration of soft ban);
- Expiry time frame settings (inc. password expiry, share link expiry, pin code expiry, inactive account expiry);
- Multi-Factor Authentication (inc. MFA enabling, MFA type, users' permissions requiring MFA, frequency of MFA sign-in checks).

6. Responsibilities

6.1 Hierarchy of use and responsibilities

The level and hierarchy of organisational and individual responsibilities, along with any authority, needs to be established and documented when HFRS is being both specified, fitted, used and data analysed. The following indicates the responsibilities to the fitment and use of HFRS and to what those responsibilities entail.

6.2 HFRS Manufacturer Responsibilities

System Design & Production	
a) Design Compliance	• Ensure system meets all required standards and certifications • Compliance with host machine OEM's requirements • Maintain CE/UKCA marking compliance • Implement and maintain quality management system • Design for stated environmental conditions • Ensure 95% minimum detection accuracy
b) Documentation	• Produce and ensure provision as per regulations on comprehensive technical documentation • Supply installation manuals and guidelines • Maintain up-to-date risk assessments • Provide declaration of conformity • Supply calibration procedures
c) Testing & Validation	• Conduct type approval testing • Perform EMC testing • Validate system performance • Document test results • Maintain test records
Support & Maintenance	
d) Technical Support	• Provide technical helpdesk • Offer troubleshooting guidance • Supply software updates • Maintain spare parts availability • Provide technical training
e) System Updates	• Manage software version control • Issue security patches • Provide firmware updates • Maintain backward compatibility • Document all system changes

Data Management	
f) System Security	• Implement cyber security measures • Maintain data encryption standards • Ensure GDPR compliance • Provide secure communication protocols • Monitor system vulnerabilities

6.3 Machine Owner/Hirer Responsibilities

System Management	
g) Installation & Maintenance	• Ensure proper system installation • Maintain calibration schedule • Conduct regular inspections • Keep maintenance records • Monitor system performance
h) Training	• Provide operator training • Maintain training records • Update training materials • Ensure competency assessment • Provide refresher training

6.4 Operational Management

Operational Management	
i) Daily Operations	• Implement daily check procedures • Maintain operational records • Monitor system performance • Report system faults • Manage alert responses
j) Compliance	• Maintain required certifications • Update risk assessments • Ensure GDPR compliance • Monitor regulatory changes • Keep documentation current

6.5 Data Handling

Data handling	
k) Data Management	• Maintain data storage systems • Ensure data security • Manage access controls • Handle data requests • Monitor data quality

6.6 User Responsibilities

Site Management	
l) Site Integration	• Conduct site risk assessments • Implement traffic management plans • Maintain exclusion zones • Manage pedestrian routes • Control site access
m) Operational Control	• Monitor system usage • Maintain site records • Report system issues • Enforce safety procedures • Control work permits

6.7 Personnel Management

Personnel Management	
n) Worker Safety	• Ensure worker training • Maintain PPE requirements • Enforce safety procedures • Monitor compliance • Report incidents
o) Visitor Management	• Control site access • Provide visitor induction • Enforce safety rules • Monitor visitor movement • Maintain visitor records

6.8 Emergency Procedures

p) Incident Management	• Maintain emergency procedures • Report accidents/incidents • Investigate occurrences • Document findings • Implement corrective actions

6.9 Shared Responsibilities

Communication	
q) All parties should:	• Maintain clear communication channels • Report system issues promptly • Share relevant information • Document communications • Follow escalation procedures
Safety Management	
r) Joint obligations:	• Maintain safety standards • Report safety concerns • Participate in investigations • Share safety information • Implement improvements
Documentation	
s) Shared requirements:	• Maintain relevant records • Share necessary documentation • Update procedures as required • Ensure document accessibility • Protect confidential information

6.10 Legal Compliance

Regulatory Requirements	
t) All parties must comply with:	• Health and Safety at Work Act • PUWER Regulations • CDM Regulations • GDPR Requirements • Relevant industry standards
Liability Management	
u) Insurance Requirements:	• Maintain appropriate insurance • Document liability arrangements • Update coverage as needed • Report relevant incidents • Manage claims properly

6.11 Dispute Resolution

Process	
v) Resolution procedure:	• Initial discussion between parties • Formal written notification • Management escalation • Third-party mediation • Legal proceedings if required
Documentation	
w) Record keeping:	• Document all disputes • Maintain communication records • Record resolution attempts • Store outcome documentation • Review for process improvement

6.12 Record Keeping (Non-GDPR)

The following list indicates the types of information required for supporting documentation that would be classed as external to the scope of GDPR:

- Installation records;
- Calibration data;
- Maintenance records;
- Testing results;
- Training records;
- Incident reports.

For record keeping purposes, the following factors should be taken into account:

- Minimum recommended 3-year retention;
- Electronic and physical backup;
- Regular review and updates
- Accessibility requirements.

7. Education and Behaviours

7.1 Training and behaviours – all related and unrelated occupations

Training programmes, both dedicated and tool-box talks, are crucial for site-based health and safety for which should be enabled for relevant occupations such as machine operators, site operatives, supervisors and managers. The emphasis, particularly at operative level, should focus on behaviours and attitudes to machine safety.

Other factors to be taken into account for learning is cognitive over-processing by the operator and that a reliance should not be made on HFRS alone. Observation and sensory skills and actions need to be maintained.

7.2 Scope of relevant occupations and roles

As a key safety aid, the function, attributes and information collected and analysed by HFRS should be understood by all site-based occupations managing, supervising or working with or near to plant. The level and depth of understanding will vary, depending on the relevance of the occupation to plant operations, but the scope of roles would include, but not be limited to:

- Site managers;
- Site supervisors;
- Plant operators;
- Plant marshallers;
- Direct supporting operatives (banksman);
- Non-related site-based occupations;
- Plant installers, maintenance and delivery personnel.

7.3 Course programmes/syllabus, knowledge requirements

Training and familiarisation on the procedures to dealing with and being in proximity to, HFRS, should be thoroughly embedded in regular induction and tool-box talk programmes from the outset as a major aid to personal safety and not just through one-off familiarisation programmes. Courses should not just focus on the technicalities or procedures of HFRS use, but to mould behaviours so that negating zone infringement becomes second nature and why this should always be avoided, both for personal safety and to maintain site social-based responsibilities.

Figure 9: Example of a transgression of the danger area

Operator Training

The following topics should be covered within a dedicated training programme. A sample course syllabus can be found in Annex C:

- Incident data;
- HFRS familiarisation;
- Blind spots on typical machine types;
- In-cab displays;
- Alert response procedures inc. signalling;
- Working with HFRS;
- Daily check procedures and fault identification;
- Risk assessment requirements and compliance;
- Emergency procedures;
- Site traffic routing, safe access and exclusion zones.

Management Training

In addition to the operator course content, the following additional topics should be covered within a dedicated training programme. A sample course syllabus can be found in Annex C:

- System capabilities and limitations;
- Data access and analysis;
- Maintenance requirements;
- Risk assessment procedures.
- Establishing traffic management, site access and exclusions zones;
- Managing pedestrian access and routes.

Operative Training

- HFRS familiarisation;
- External alert response procedures, inc, if a self-propelled machine moves near to an operative;
- Site traffic routing, safe access and exclusion zones;
- Thumbs-up and other signalling methods;
- Risk assessment requirements and compliance;
- Re-training/personal support due to constant transgressions.

8.4 Behavioural changes through use and data analysis

Where collated data indicates high or concerning levels of HFRS zone transgressions, this will likely indicate that a number of factors are lacking in designated control methods as identified through risk assessment. See Section 4.9.

An important factor of frequent zone incursions, particularly by regular individuals or groups, is to focus on behavioural aspects of learning by establishing, from the relevant individuals, their rationale of frequently or repeatedly entering or being in close proximity to an active machine, along with why they are ignoring the inherent dangers of doing so in a bid to implementing a behavioural modification programme.

Before subjecting individuals through a behavioural change programme, the causes of continual same-person transgression needs to be analysed, as other factors e.g. site layout, work activity etc. may be a core cause. See Section 5.4.

The Health and Safety Executive provide further information on behavioural safety approaches at https://www.hse.gov.uk/humanfactors/topics/behaviouralintor.htm

8.5 Awareness/actions through alarm activations and indifference issues

Continual HFRS-controlled zone transgression by individuals, where training and behavioural modifications appear to have limited effect, mean that the transgressor becomes non-compliant with the requirements of the Health and Safety at Work Act – Section 7; where they have a duty to take reasonable care of themselves as well as others. This may need to be considered as a work-conduct issue and as with any health and safety transgressional issue, potentially dealt with through a management disciplinary process in order to safeguard themselves and others.

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Annex A – Fault Reporting Procedures

Where faults may occur, the following hierarchy and procedures should be adopted at all times.

Critical Faults (Immediate Stop) *The following listed faults should necessitate an immediate stopping of operations until rectification procedures are investigated. Operations should either not continue or that other agreed procedures, to ensure safe working practices, are risk-assessed by the user. See Section 3.11 for further guidance.*	
a) Sensor Failure	• **Initial Action**: Stop machine, secure area • **Report:** Immediate supervisor notification and asset owner • **Resolution:** Investigation by authorised technician
b) System Non-response	• **Initial Action:** Stop machine, power cycle system • If persists, report fault • **Resolution**: System diagnostic required
c) Display Failure	• **Action**: Stop machine if no visual confirmation • **Report:** Log fault, arrange maintenance and inform asset owner • **Resolution**: Display unit replacement/repair
Non-Critical Faults (Controlled Response)	
Intermittent Alerts	• **Action**: Note conditions causing issue • **Report**: End of shift documentation • **Monitor**: Increased vigilance required
External Alarm Issues	• **Action**: Verify internal systems functional • **Report:** Document for maintenance • **Continue**: If internal systems operational
GPS/4G/5G Issues	• **Action**: Note location and conditions • **Report:** Technical support notification • **Monitor:** Regular connection checks

Response Protocol	
Immediate Actions	• Initially secure machine • Record fault details • Notify supervisor and asset owner • Isolate or follow agreed procedures to allow continued operations under controlled conditions • Document incident

Response Protocol *(cont'd)*	
Resolution Process	• Fault assessment by qualified technician • Repair/replacement as required • System reset and testing • Documentation of resolution • Return to service authorization
Return-to-Service Requirements	• Full system test completion • Documentation review • Supervisor sign-off • Operator briefing • Test operation period

Documentation Requirements	
Fault Record	• Date and time of fault • Machine details • Fault description • Initial actions taken • Resolution measures • Sign-off by authorised person
System Reset Procedure	• Power down sequence • System diagnostic check • Calibration verification • Zone testing • Alert system verification

Annex B – HFRS Specification

The following indicates a specification and accuracy testing requirement established for industry and plant sector requirements. Please note that some of the specifications, such as system accuracy, may not currently have an applicable standard, but are listed as an industry aspiration to encourage future developments of more precise and reliable systems.

a) Factors for accuracy testing including:

- All testing should achieve a minimum of 95% detection accuracy of human form and an acceptable level of accuracy of not detecting non-physical human forms (false positive) based on standards as identified by bodies such as MIRA;
- False positive recording and rectification - with feedback to the supplier to aid future system improvements/updates (following relevant authorisations etc. – See Section 4.5);
- Testing should be documented and retained for audit purposes;
- Testing needs to demonstrate consistent performance in varying environmental conditions;
- Regular validation of accuracy should be required;
- Testing must be conducted in various environmental conditions;
- All test results should be verified by a competent person.

b) The following information should be recorded for all test scenarios:

- Date and Time;
- Location;
- Machine type, make and model;
- Detection system type/make/model etc;
- Detection Configuration;
- Weather conditions;
- Clothing/PPE colour testing matrix;
- Pedestrian position variations.

c) When testing to establish environmental conditions, testing should be undertaken under the following conditions:

- Daylight (>1000 lux);
- Low light (min 0.1 lux);
- Adverse weather (rain, fog where safe);
- Varying temperatures within the operating range (- 20°C to + 60°C).

d) When conducting colour test detection, the following PPE colours should be, as a minimum separately identified:

- Yellow;
- Orange;
- Blue;
- Black;
- Grey;
- White.

e) When conducting position testing, the test detection criteria needs to identify, as a minimum, a person in following positions:

- Standing (static);
- Crouching (static);
- Walking (dynamic);
- Running (dynamic);
- Rotating (dynamic);
- Kneeling (static);
- Lower body obscured (static);
- Upper body obscured (static);

f) The test procedure should comply with the following process:

- Marking out of a 1m x 1m grid*;
- Recording baseline environmental conditions;
- Immediate positioning test subject in each grid square;
- Movement of test subject through walking and running at various directions;
- Recording successful and unsuccessful detections;
- Repeating for each PPE colour;
- Repeating for each position type;
- Calculating detection accuracy percentage;
- Documenting any detection failures or anomalies;

**** Note:** for the marking out of the 1m x 1m test grid, initial testing should be conducted on a test bed. This should be verified, ideally, on the relevant machine (dependant on customer fitting or purchasing requirements.*

g) Any acceptance criteria needs to ensure that:

- A minimum 95%l detection accuracy rate was attained in each zone;
- There is no complete detection failures in the designated inner zone;
- There is no more than 3 consecutive failed detections in the designated outer zone;
- The system maintained performance during continuous operation.

Annex C – Operative and Manager Training Programme Syllabus

Key: 1 = Appreciation; 2 = Overview 3 = Descriptive

Learning Outcome *The Learner will need to know and understand:*	**Syllabus Content**	**Learning Level – 1 to 3**		
		Operator	**Manager**	**Operative**
Reasons for HFRS fitment	• Types of incidents • Outcomes of incidents • Legal compliance	3	3	3
HFSR componentry and fitment	• Types of HFRS • Range of eligible machine types • Sensors and locations • Scope of sensors and how and what they sense • Zoning adjustments • Machine blind-spots • System advantages and limitation to fitment and use • Setting up and pre-setting alert zones • Environmental aspects to sensing • HFRS accuracy	2	3	1
Types of in-cab displays and warning systems	• Visual componentry • Audible componentry • Clarity of information and languages • Settings • Systems protection from damage • In-cab limitations of componentry	3	3	2
Alert response procedures inc. signalling	• Types of alerts • Internal and external indications inc visual and audible • Procedures for incursions – operator and operative • False alert procedures • Adjusting/recalibration pre-set alerts for local requirements • Considerations for zone resetting • Authorisation for zoning amendments • Continual alerts/transgressions • Re-training/familiarisation • Tampering with systems	2	3	3

Working with HFRS	• Daily and on-going checks • Weekly checks • Fault identification • Limitations to sensing and alerts • Machine-approaching procedures and visual signalling • Maintenance requirements	3	3	1
Data access and analysis.	• Types of collected data and format • Downloading/transferring from machine to external storage • Compliance requirements with GDPR • Use of data to identify incursion frequency and types • Data security and long-term storage • Controlling access to data	1	3	1
Risk assessment procedures.	• Zoning requirements • People/plant interface protocols • Hierarchy of all control methods • Hierarchy of responsibilities and controls • Factors for RAMs construction • Alarm/alert disablement requirements	1	3	1

Annex D Hiring of Plant fitted with HFRS

There are occasions when a customer, or the customer's customer (the 'end-user'), may ask the plant owner/supplier to fit HFRS to plant and machinery which the plant owner/supplier is supplying for use on the customer's site, or in certain circumstances, the end-user's site.

HFRS can record footage from which it may be possible to identify individuals, such as employees of the customer or end-user. The use of HFRS is therefore governed by relevant data protection legislation such as the UK GDPR, which imposes a range of onerous obligations regarding the use of the HFRS and the use of any data collected by the HFRS. Failure to comply with these rules can carry significant penalties.

Legal advice supplied to the Plant Safety Group by the Construction Plant-hire Association advises that if a plant owner or supplier supplies plant and machinery with HFRS fitted, there is a risk that the plant owner/supplier may be subject to obligations (and potential liabilities and penalties) under the UK GDPR, even if the plant owner/supplier does not have access to the recordings itself.

Processing personal data on behalf of customers and end-users is outside the scope of what plant owners/suppliers usually do when supplying plant and machinery and is therefore may not be addressed by hire conditions e.g. the CPA's Model Conditions and may not be adequately covered by plant owners'/suppliers' own data protection documentation or insurance policies.

The following provides the plant hire sector with a general understanding of the issues and options available in relation to supplying HFRS. However, it is important to be aware that this is a complex area of law and the hire sector, plant owners and users should obtain independent legal advice if they have any concerns or wish to understand how this might affect their individual businesses.

a) Plant owners/suppliers should consider refraining, wherever possible, from supplying 'working' HFRS with any plant and machinery. This will avoid any personal data being collected and therefore avoid the application of UK GDPR obligations and liabilities.

b) Should either the customer or end-user insist that 'working' HFRS are required on site, e.g. for Health and Safety reasons, and the plant owner/supplier is willing to supply them, then the plant owner/supplier should insist that the customer or end-user put in place a specific 'service contract/agreement' in place between themselves and either the HFRS manufacturer or an appointed data service organisation.

c) The plant owner/supplier should make clear in the hire agreement that it is not responsible for the collection and processing of data through the HFRS and equally it should ensure that it has agreed with the HFRS manufacturers that any agreement for the use of the HFRS will be directly between the manufacturer and the customer or end-user.

d) The plant owner/supplier must ensure that it does not become involved in any issues relating to the collection, storage or retrieval of any data from the HFRS. This will avoid the plant owner/supplier being involved in the processing of personal data and therefore avoid the plant owner/supplier becoming subject to UK GDPR obligations and liabilities.

e) There will be occasions when the plant owner/supplier may wish to offer 'working' systems to their customer (or for the end-user's benefit) and to take direct responsibility to the customer (or end-user) for the operation of the HFRS. This will be a commercial decision, but the plant owner/supplier must be aware that the provision of this service may not be addressed by certain hire conditions e.g. the CPA's Model Conditions of Hire.

The plant owner/supplier will therefore need to prepare additional legal terms to cover the provision of this service and the UK GDPR implications of providing this service. It is strongly advised that the plant owner/supplier should obtain independent legal advice and discuss this with their insurance broker/provider before making any contractual commitment(s) with their customer.

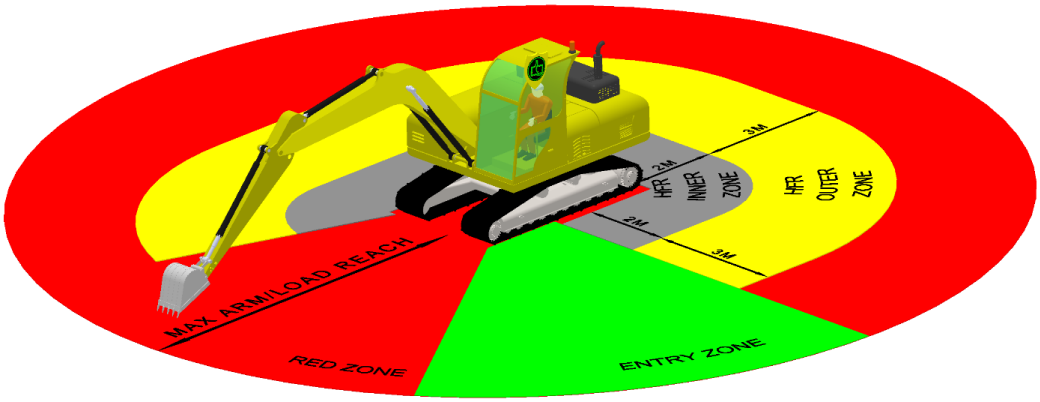
f) Given the work involved in fitting and removing HFRS, it may not always be practical to fit and remove HFRS separately for each individual hire. This may result in plant or machinery fitted with HFRS being supplied to a customer or end-user which has not requested HFRS. In this case, it is essential that the HFRS are deactivated prior to the plant or machinery being supplied to the customer or end-user. Supplying HFRS with 'working' HFRS where this has not been requested by the customer or end-user is likely to place the plant owner/supplier in breach of the UK GDPR. It is important to be aware that the supply of plant or machinery with deactivated HFRS may cause confusion or concern to customers or end-users (or their employees) who may not be aware that the HFRS have been deactivated, and the plant owner/supplier is therefore advised to take reasonable steps to make it clear that the HFRS is deactivated.

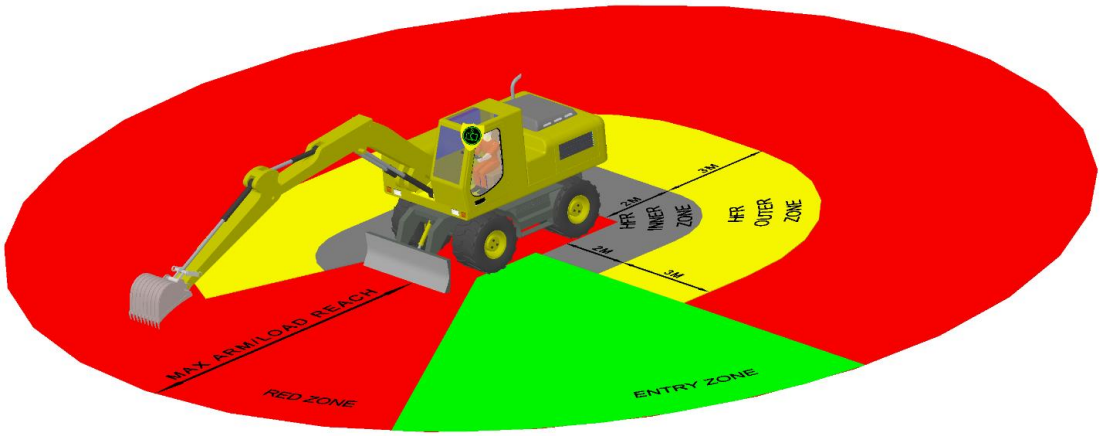
Annex E HFRS Detection Zones

Annex E provides 3D imagery in support of the detection zoning specifications as outlined in Section 3.4

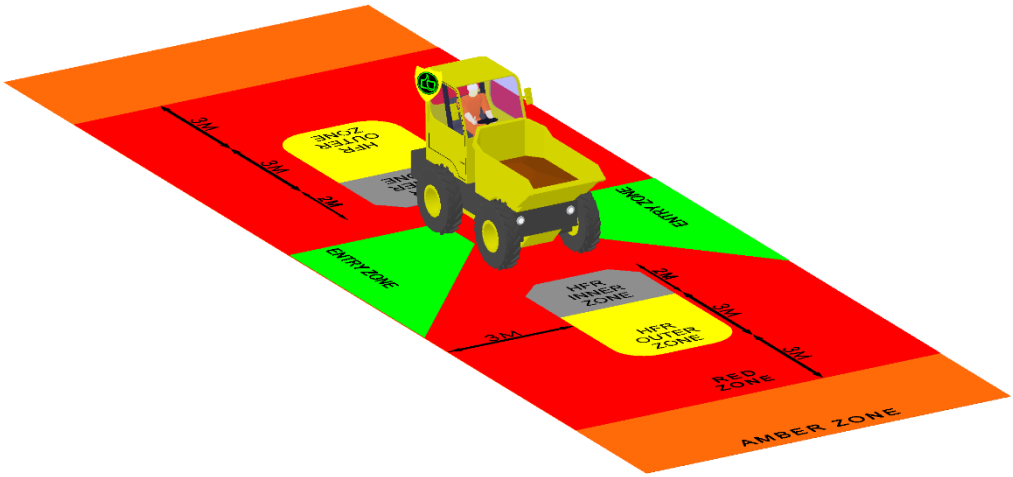
Note: For clarification, the indicated red and amber coloured zones in the following illustrations relate to people/plant interface and control measure requirements, over and above the initial HFRS activation zoning specifications within Section 3.4. The relevant colours used are only illustrative for this section.

a) 360° Excavators

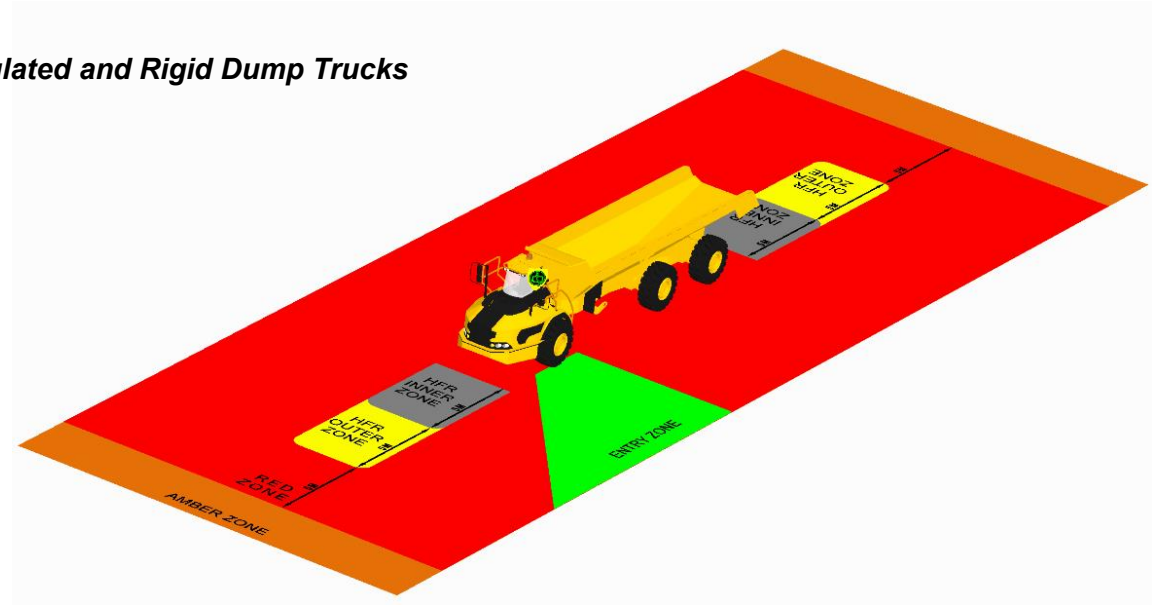




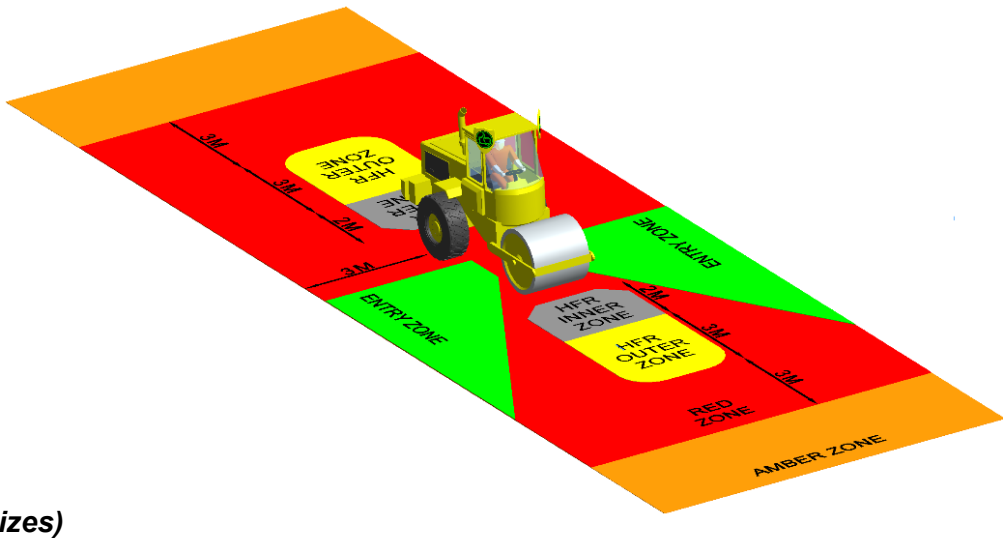
b) Forward Tipping Dumpers



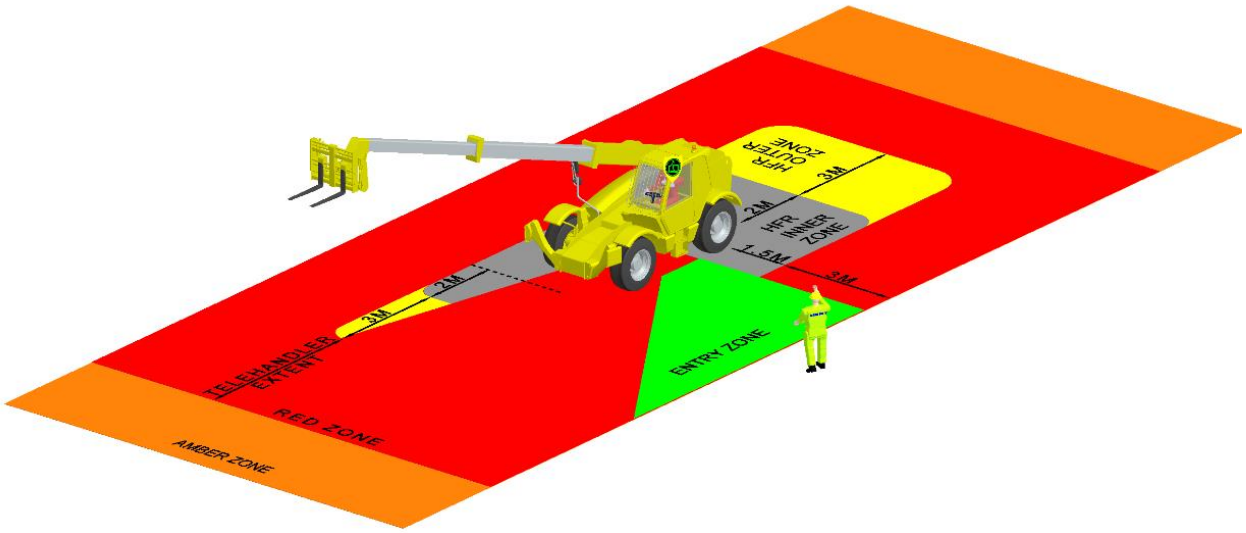
c) Articulated and Rigid Dump Trucks



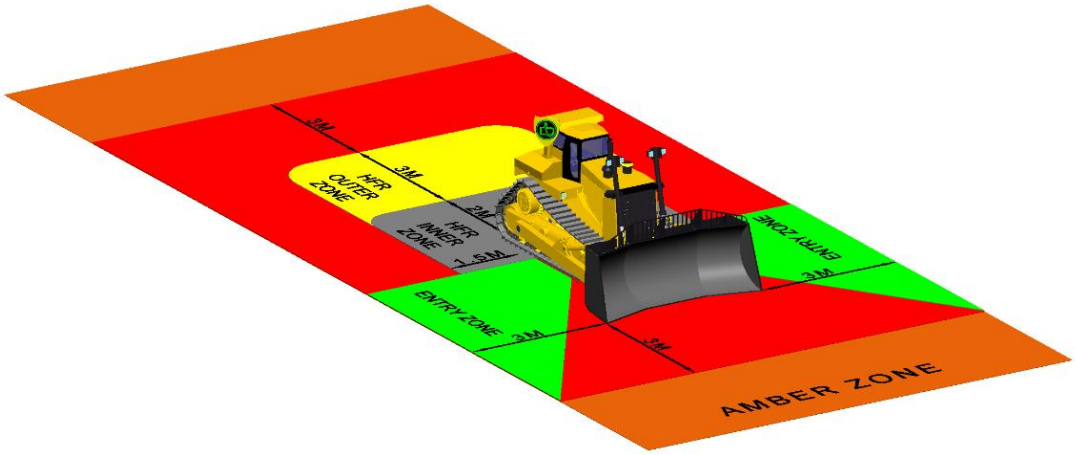
d) Rollers/Compactors (cabbed types)



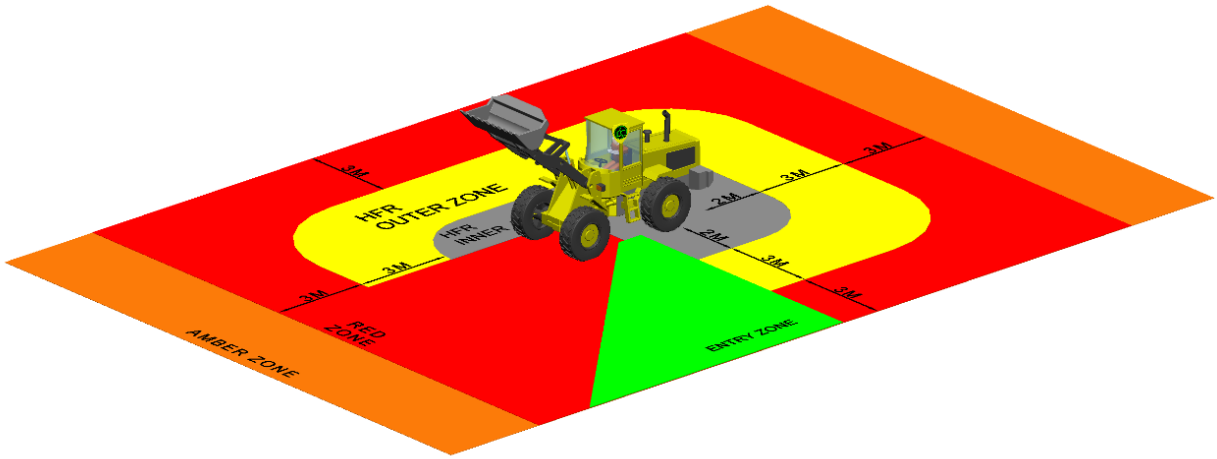
e) Telehandlers (All Sizes)



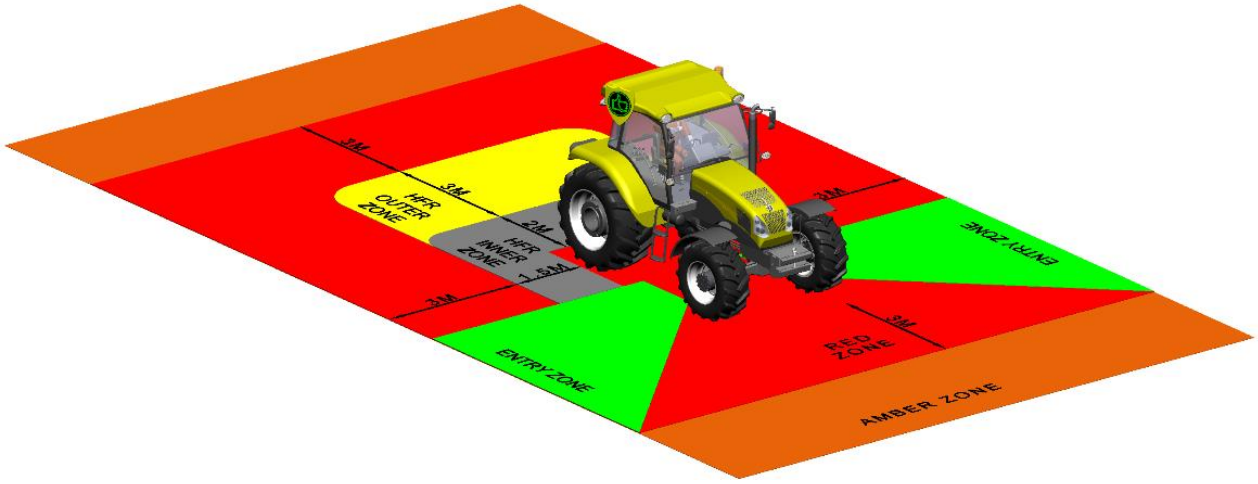
f) Dozers



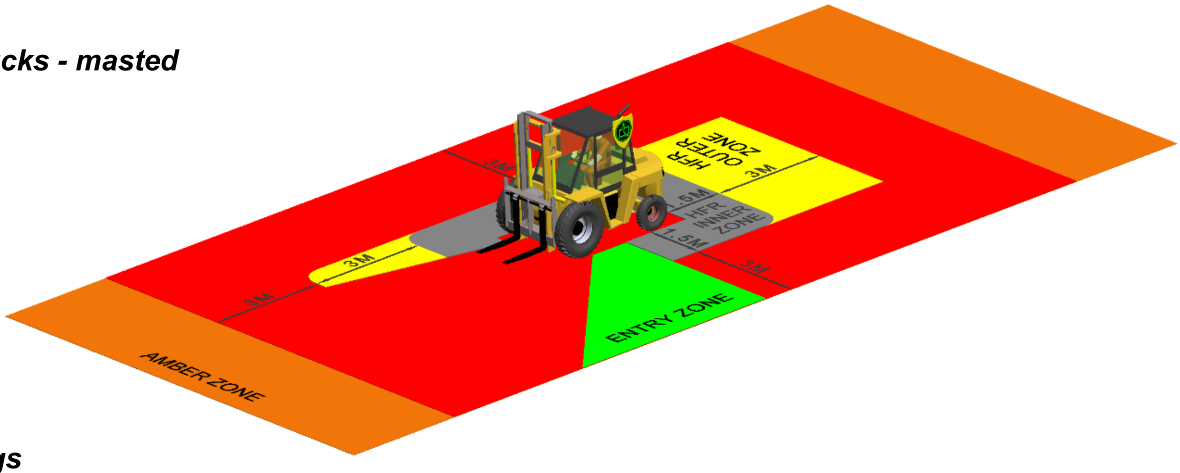
g) Wheeled Loaders and 180° Excavators



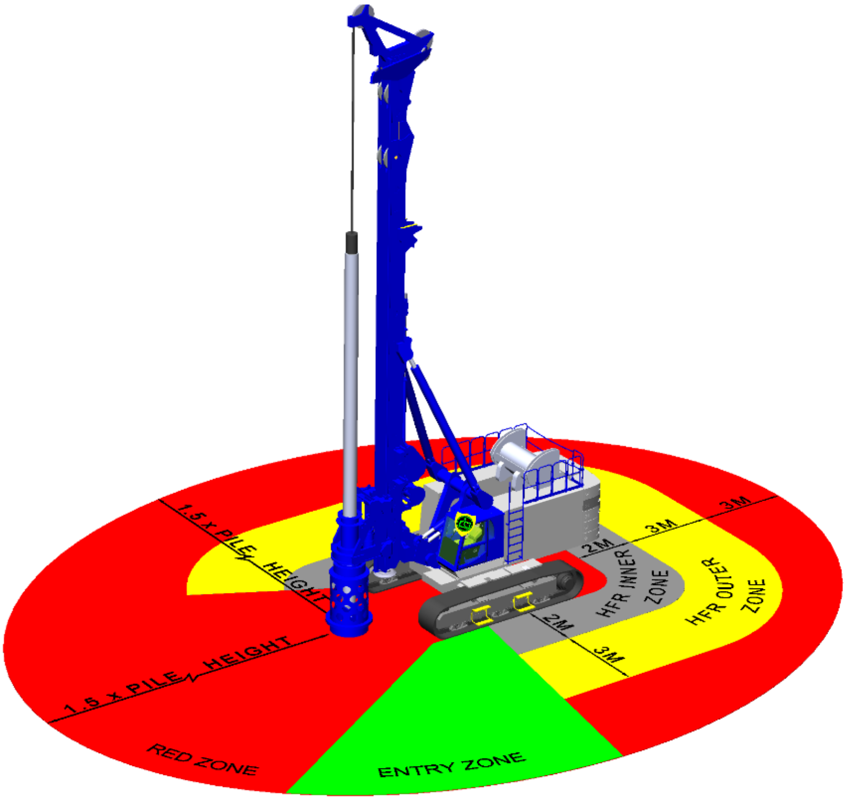
h) Agricultural-based Tractors



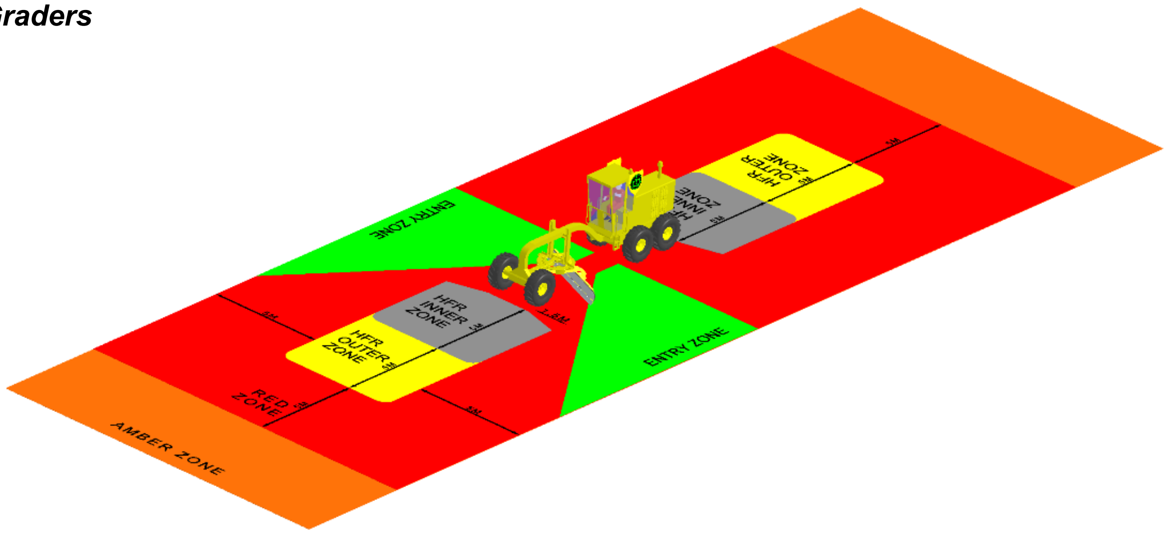
i) RT lift Trucks - masted



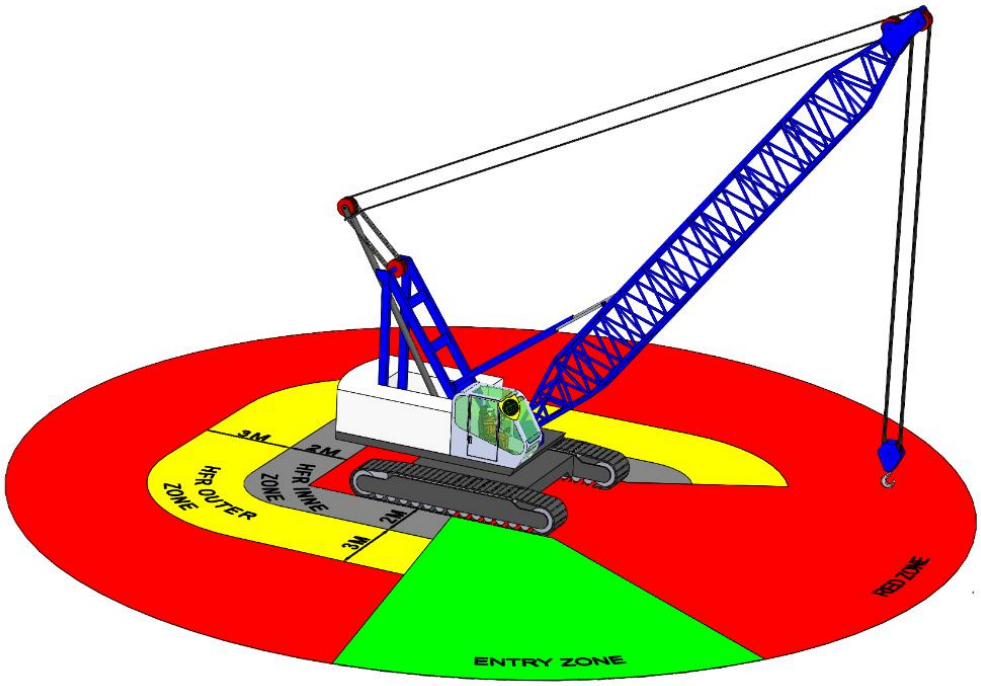
j) Piling Rigs



k) Graders



l) Crawler Cranes



Annex F Legal, Regulative & Applicable Standards & Guidance

1. Relevant Standards

HFRS should meet any relevant CE and / or UKCA Certification and marked accordingly.

Possible standards that may influence the design and manufacture of HFRS:

a) ISO 13849: Safety of machinery - Safety-related parts of control systems.

b) ISO 16001: Earth-moving machinery - Object detection systems and visibility aids inc.

2. Relevant Standards

HFRS should meet any relevant CE and / or UKCA Certification and marked accordingly.

Possible standards that may influence the design and manufacture of HFRS:

a) ISO 13849: Safety of machinery - Safety-related parts of control systems.

b) ISO 16001: Earth-moving machinery - Object detection systems and visibility aids inc.

- Detection zone accuracy requirements
- System response time specifications
- Environmental performance criteria

c) ISO 21815: Earth-moving machinery - Collision warning and avoidance inc.

- Alert system requirements.
- System integration specifications
- Performance validation criteria

All systems can meet the following electromagnetic compatibility:

d) / ISO 13766 requirements inc.

- Immunity to electromagnetic interference
- Emission control specifications
- Testing and validation procedures

Sensor Safety Requirements may be in compliance with:

e) IEC 62998: Safety-related sensors inc.

- Sensor reliability specifications
- Environmental performance requirements
- Validation testing procedures.

3. GDPR requirements and regulatory compliance inc ISO 27001 (information security) etc.

Regulative Data Protection requirements inc:

- GDPR compliance
- Registered with the ICO
- Cyber Essentials Certification

- An IT Policy covering:
  - Data collection limitations
  - Storage security specifications
  - Access control requirements
  - Retention period compliance

Annex G – Further Information and Links

PUWER - https://www.hse.gov.uk/work-equipment-machinery/puwer.htm

CDM - https://www.hse.gov.uk/construction/cdm/2015/index.htm

Data Protection - https://www.gov.uk/data-protection

ISO: https://www.iso.org/standards.html

Supply of Machinery (Safety) Regulations 2008: Great Britain: https://www.gov.uk/government/publications/supply-of-machinery-safety-regulations-2008/supply-of-machinery-safety-regulations-2008-great-britain

Information Commissioners Office - https://ico.org.uk/

Annex H Working Group Membership

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Mark Anderson	GAP Group
Matt Ross	Sunbelt Rentals
Paul Caruana	Safety Shield Global
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Use of Machine-mounted Human Form Recognition Systems

Good Practice Guide

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